THREE-TERMINAL FILTER USING AREA FLEXURAL VIBRATION MODE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a three-terminal filter using area flexural vibration mode for use in, for example, an AM filter or other suitable apparatus.

2. Description of the Related Art

Conventional three-terminal filters used in a kHz band include a filter using the area expansion vibration mode or a filter using the length vibration mode.

Fig. 1 illustrates an example of an AM three-terminal filter B using the area expansion vibration mode.

In this filter B, a center electrode 11 is provided on the surface of a central portion of a piezoelectric ceramic substrate 10 having a square shape, a ring electrode 12 that surrounds the center electrode 11 is provided on the exterior thereof, and a ground electrode 13 is provided on the entire back surface. An input terminal 11a, an output terminal 12a, and a ground terminal 13a are respectively connected to the center electrode 11, the ring electrode 12, and the ground electrode 13.

Fig. 2 shows a circuit diagram of the three-terminal filter B of Fig. 1.

In the three-terminal filter B using the area expansion vibration mode, the resonance frequency is determined by the length of one side of the three-terminal filter B. For example, if a 40kHz filter is desired, the length of one side of the filter is 50 mm.

In recent years, miniaturization of electronic devices is increasingly important, and thus, electronic components are also required to be made smaller and thinner. The above-described filter is relatively large and cannot be sufficiently miniaturized. Therefore, the three-terminal filter using the area

expansion vibration mode was applicable only for filters having a frequency of about several 100kHz or more.

In a three-terminal filter using the length vibration mode, as with the filter using the area expansion vibration mode, since the resonance frequency is determined by the shape (length) thereof, size-reduction is very difficult.

SUMMARY OF THE INVENTION

To overcome the above-described problems, preferred embodiments of the present invention provide a three-terminal filter using the area flexural vibration mode that is much smaller than the filters using the area expansion vibration mode or the length vibration mode, and in which the frequency is adjusted by changing the thickness and length of the filter.

Moreover, the three-terminal filter according to preferred embodiments of the present invention achieves lower frequencies than conventional three-terminal filters of equivalent size.

According to preferred embodiments of the present invention, three electrodes having substantially square shapes and two piezoelectric layers having substantially square shapes are alternately laminated. The piezoelectric layers are polarized in the same direction as the thickness direction or in the reverse direction thereof. One surface electrode functions as an input electrode, another surface electrode functions as an output electrode, and an internal electrode functions as a ground electrode. As a result, a three-terminal filter using the area flexural vibration mode is provided.

In a substantially rectangular resonator using the bending vibration mode, a long-side bending vibration mode and a short-side bending vibration mode occur. However, the frequency of the short-side bending vibration mode and the long-side bending vibration mode are approximately equal when the shape thereof is approximately square. When the resonator is substantially square, both the long-side bending vibration mode and the short-side bending vibration mode overlap, thereby generating a very large area flexural vibration mode.

In a resonator using the area flexural vibration mode according to preferred embodiments of the present invention, the piezoelectric layers, in which the direction of the polarization and the direction of the electric field are the same, contract in a direction of a flat surface. The piezoelectric layers, in which the direction of the polarization and the direction of the electric field are reverse, expand. Therefore, an area flexural vibration mode is generated in the resonator. In such a resonator using the area flexural vibration mode, compared with the piezoelectric resonator using the area expansion vibration mode, if both resonators have the same resonance frequency, the size of the resonator using the area flexural vibration mode is much smaller. Conversely, if both resonators are the same size, a filter having a much lower frequency is obtained with the resonator using the area flexural vibration mode.

In a resonator using the area expansion vibration mode, the resonance frequency is determined only by the length of one side. On the other hand, in a resonator using the area flexural vibration mode, the resonance frequency is determined not only by the length of one side, but also by the thickness of the resonator. Therefore, the resonance frequency can be adjusted by changing the side length and the thickness of a resonance element.

Moreover, in the resonator using the area flexural vibration mode, compared with the resonator using the area expansion vibration mode, because the two-layered piezoelectric layers are laminated, even when the overall thickness is the same, the thickness of each piezoelectric layer can be made thinner to be approximately 1/2 of conventional thicknesses. Therefore, the capacitance between terminals, that is, between the input electrode and the ground electrode, and between the output electrode, and the ground electrode is approximately doubled.

Other features, elements, advantages and characteristics of the present invention will become more apparent from the detailed description of preferred embodiments thereof with reference to the attached drawings.